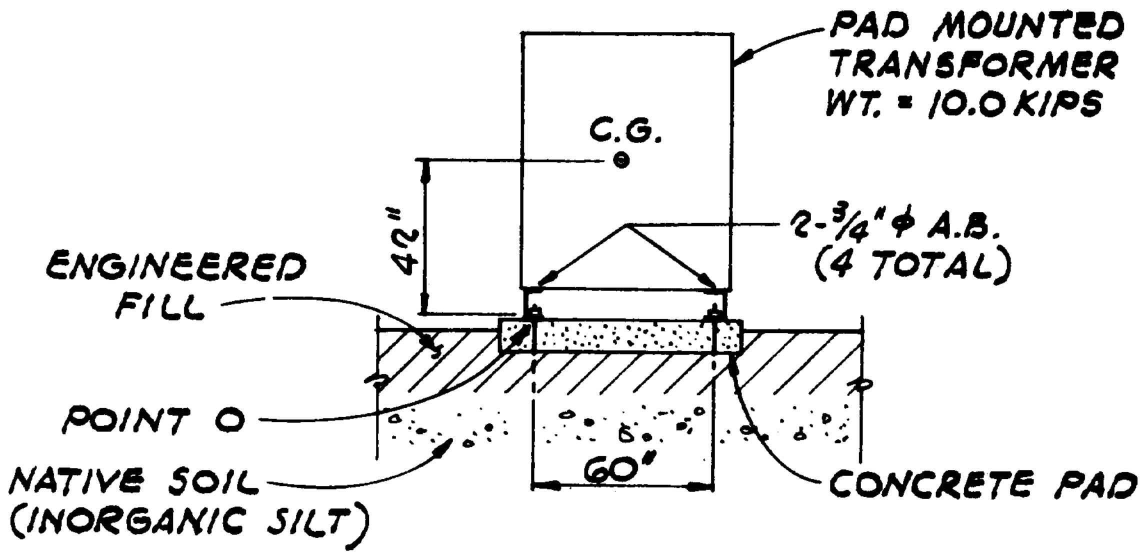
APPENDIX E

DESIGN EXAMPLES—MECHANICAL AND ELECTRICAL EQUIPMENT

E-1. Introduction. The design examples in this appendix are to illustrate principles, factors, and concepts involved in seismic design. These are not mandatory; and other equivalent methods, materials, or details complying with this manual and applicable agency guide specifications may be used.

E-2. Design Examples:

Fig. No.	*Description of Design Examples*
E-1	*Pad-Mounted Transformer*. Illustrates the seismic design of a typical, rigidly mounted item of equipment on the ground.
E-2	*Cooling Tower in Building.* Presents analysis for a rigidly mounted cooling tower in a multi-story building.
E-3	*Unit Heater—Flexible Brace.* Analysis of a unit heater not rigidly braced.
E-4	*Unit Heater—Rigid Support.* Demonstrates the reduction of the lateral seismic load by rigidly bracing the unit heater of figure E-3.
E-5	*Water Heater.* Indicates how a water heater in a barracks is investigated for seismic loads.
E-6	*Tank on a Building.* Demonstrates the seismic analysis of a storage tank on a building. Emphasis is placed on the period determination.
E-7	*Water Riser.* Illustrates an approximate scheme used to determine the seismic loading on pipe connections. A riser in a multi-story building is treated.



GIVEN: W = 10.0 KIPS
RIGID EQUIPMENT ON THE GROUND
ZONE 3 SEISMIC AREA AND I = 1.0

REQUIRED: CHECK ANCHOR BOLT REACTIONS DUE TO SEISMIC LOADS.

SOLUTION:

$F_p = ZI\,(2/3\ C_p)\,W_p$ (EQ 12-3)

$Z = 0.30,\ I = 1.0,\ C_p = 0.75,\ W_p = 10.0$ KIPS

$F_p = 0.30\,(1.0)(2/3)(0.75)(10) = 1.5$ KIPS

APPLIED AT CG

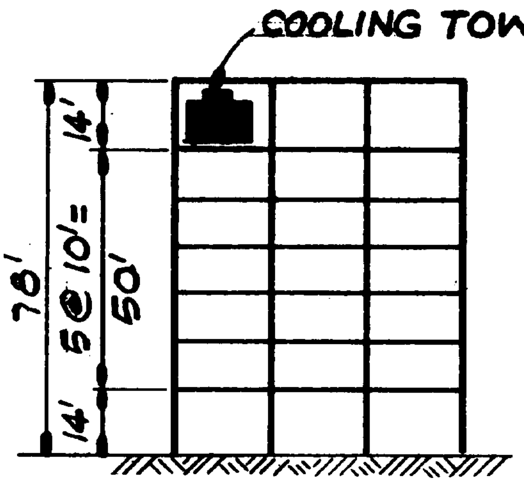
SHEAR/BOLT = 1.5/4 = 0.38 KIPS/BOLT
ALLOW. SHEAR = 1.50 KIPS/BOLT
$\therefore$ 4-¾" ϕ A.B. O.K.

CHECK OVERTURNING -
$\Sigma M_O = 0$
$42'' \times 1.5^K \ll \frac{60''}{2} \times 10.0^K$ $\therefore$ OVERTURNING O.K.

Reference: Chapter 12, paragraph 12-5a

Also Check SEAOC 1I per SEAOC 1G 2d
Rigid Non-Building Structure
V = 0.5 ZIW (SEAOC EQ 1-12)
= 0.5 x 0.3 x 1 x 10 = 1.5 KIPS Same as Above

Figure E-1. Pad-mounted transformer.



GIVEN:

WT. COOLING TOWER = 20.0 KIPS
ZONE 3 SEISMIC AREA
CONSIDER TOWER RIGIDLY MOUNTED
WT. TYP. FLOOR = 400 KIPS
100 % MOMENT RESISTING FRAME. I = 1.0.

REQUIRED:

FIND THE SEISMIC DESIGN FORCE TO BE APPLIED AT C.G. OF COOLING TOWER.

SOLUTION:

CHECK MASS RATIOS (PARA. 12-2d)
W_p/w_x FLOOR 20/400 < 0.20 O.K.
W_p/W STRUCT. 20/2800 < 0.10 O.K.

QUALIFIES AS RIGID EQUIPMENT, RIGIDLY MOUNTED IN A BUILDING (PARA. 12-3).

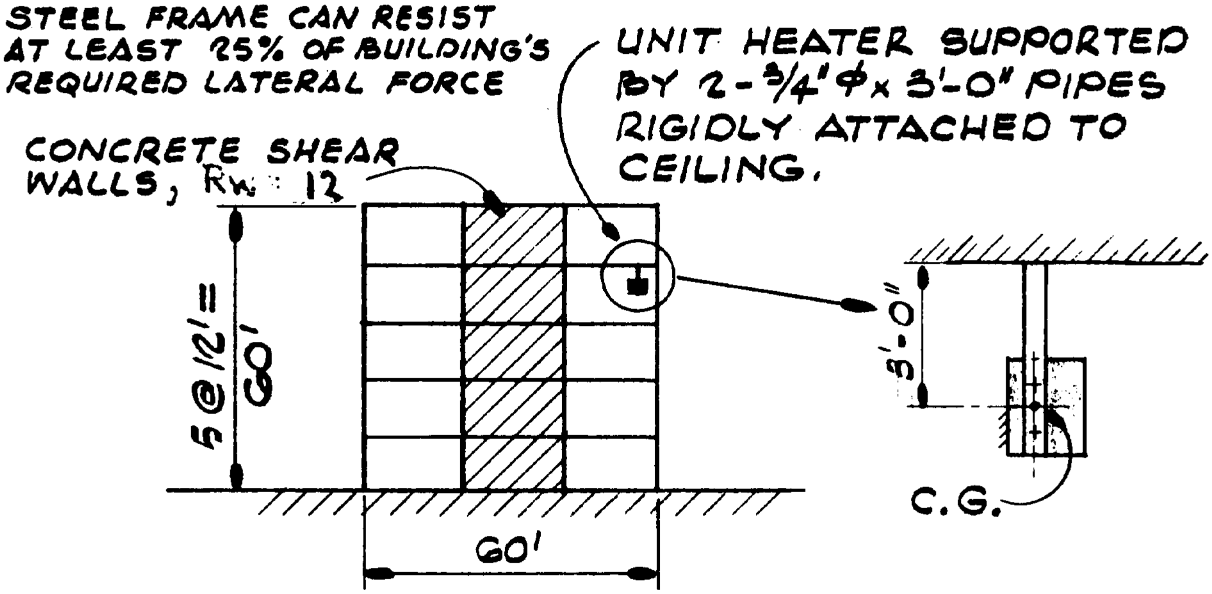
$F_p = Z I_p C_p W_p$ (SEAOC EQ 1-10)

$Z = 0.30$ (ZONE 3), $I = 1.0$

$C_p = 0.75$ (SEAOC TABLE 1-H)

$F_p = 0.30 \times 1.0 \times 0.75 \times W_p = 0.225\, W_p$
$= 0.225 \times 20 = \underline{\underline{4.5 \text{ KIPS}}}$

Figure E-2. Cooling tower in building.



GIVEN: NEGLECT EFFECTS OF ROTATION OF UNIT HEATER.

W_p = WT. UNIT HEATER = 450 LBS

w_x = WT. TYPICAL FLOOR = 500 KIPS

W = WT. STRUCTURE = 2300 KIPS

I (OCCUPANCY) = 1.0

ZONE 3 SEISMIC AREA

I_o (3/4'Φ PIPE) = 0.037 IN^4

E (PIPE) = 30×10^3 $KIPS/IN^2$

REQUIRED: FIND DESIGN SEISMIC FORCE TO BE APPLIED AT C.G. OF UNIT HEATER.

SOLUTION: CHECK MASS RATIOS: (PARA. 12-2d)

W_p/w_x FLOOR = 0.45/500 << 0.20 OK

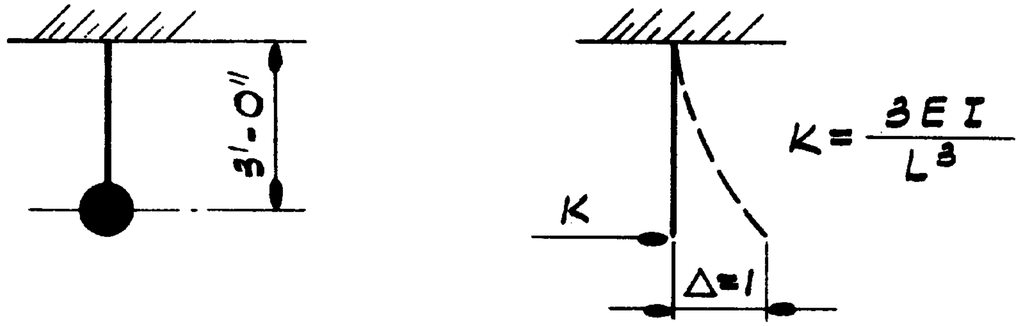
W_p/W STRUCT. = 0.45/2300 << 0.10 OK

INVESTIGATE AS FLEXIBLY MOUNTED EQUIPMENT IN BUILDINGS PARA. 12-4

$$F_p = Z I_p A_p C_p W_p \qquad \text{(EQ 12-3)}$$

Figure E-3. Unit heater-flexible brace.

Z = .30 (ZONE 3), I = 1.0, C_p = 0.75'
A_p, WHICH RANGES FROM 1.0 TO 5.0 IS DEPENDENT
ON PERIODS T_a (EQUIP.) AND T (BLDG.)
REFER TO PARA. 12-4e.



$$k = 2\left\{\frac{3(30\times10^3)(0.037)}{36^3}\right\} = 0.142 \text{ KIPS/INCH.}$$

$$T_a = 0.32\sqrt{\frac{W_p}{k}} = 0.32\sqrt{\frac{.35}{.142}} = 0.50 \text{ SEC.} \qquad (10\text{-}1)$$

T = 0.6 SEC. (FROM ANALYSIS OF BUILDING,
SEAOC EQ 1-5 AND PARA 12-4c (1))

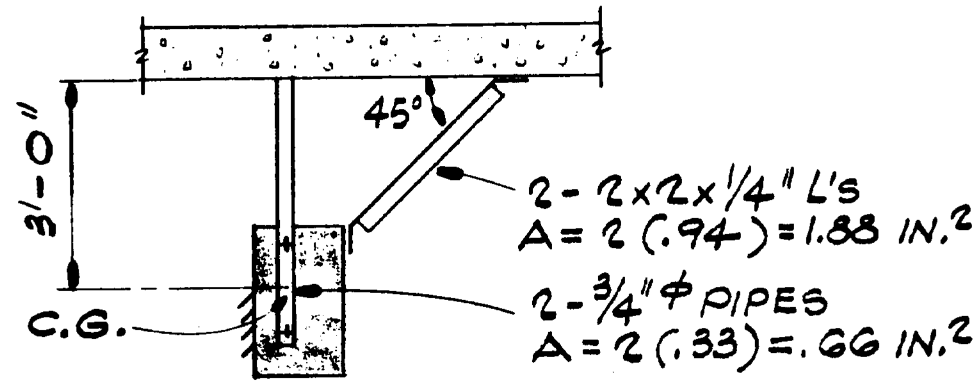
$$\frac{T_a}{T} = \frac{0.50}{0.60} = 0.83$$

USE FIGURE 12-3b: A_p = 4.90 (TABLE 12-1)

F_p = 0.30 × 1.0 × 4.9 × 0.75 W_p = 1.10 W_p
= 1.10 × 350 = 386 LBS.

NOTE: A LATERAL FORCE OF 386 LBS. WILL
OVERSTRESS THE 3/4" φ PIPE BRACES;
THEREFORE ADD DIAGONAL SUPPORTS
AS SHOWN IN FIGURE E-4.

Figure E-3. Continued.



DETAIL OF UNIT HEATER

GIVEN : USE DATA GIVEN IN FIGURE E-3

REQUIRED : FIND DESIGN SEISMIC FORCE

SOLUTION : $F_p = Z I_p C_p W_p$ (SEAOC EQ 1-10 IF RIGIDLY MOUNTED, PARA. 12-3)

CALCULATION OF T_a FOR RIGIDITY CHECK:

APPROXIMATE ANGLE CONNECTIONS BY PINS. ASSUME ALL LATERAL FORCE IS RESISTED BY BRACING ANGLES. USE ENERGY METHOD TO CALC. K_2.

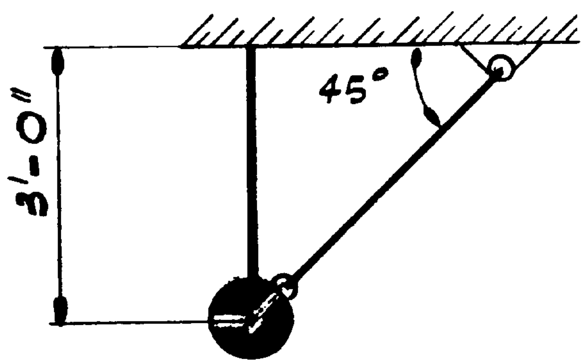
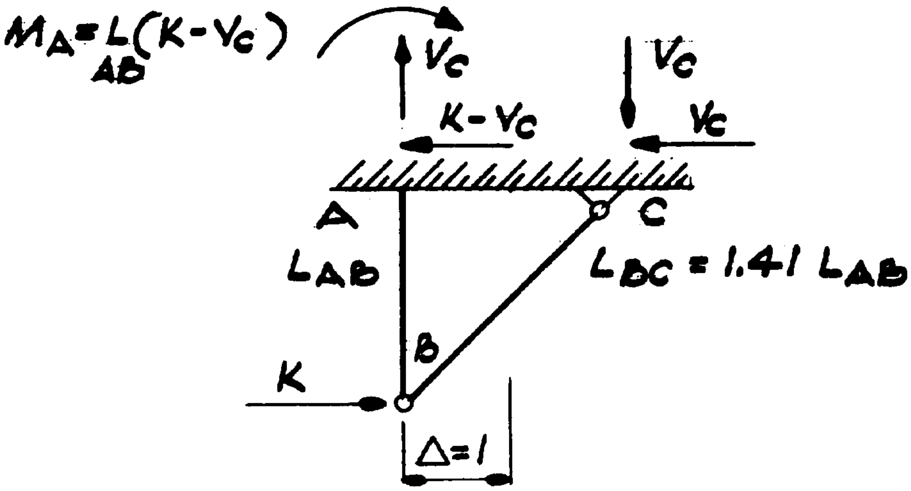


Figure E-4. Unit heater—rigid support.



ASSUME $K - V_C \doteq 0$: THIS ASSUMES ALL OF THE HORIZONTAL FORCE K IS RESISTED BY THE DIAGONAL.

$$\Sigma W_{EXTERNAL} = \Sigma W_{INTERNAL}$$

$$K\left(\frac{\Delta}{2}\right) = \frac{K^2 L_{AB}}{2 A_{AB} E} + \frac{(1.41K)^2 L_{BC}}{2 A_{BC} E}$$

$$1 = K\left(\frac{L_{AB}}{A_{AB} E} + \frac{1.41^3 L_{AB}}{A_{BC} E}\right)$$

$$K = \frac{30 \times 10^6}{\left(\frac{36}{0.66} + \frac{1.41^3 (36)}{1.88}\right)} = 2.78 \times 10^5 \text{ LBS/INCH}$$

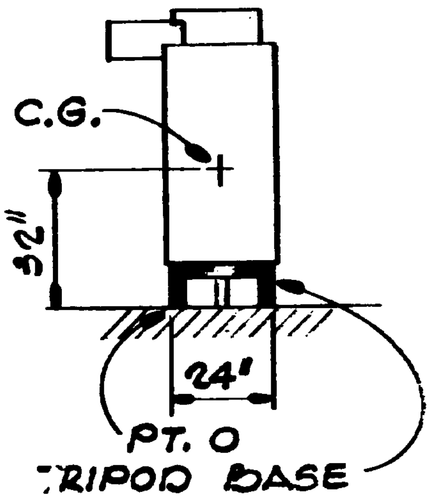
$$T_a = 0.32 \sqrt{\frac{350}{2.78 \times 10^5}} = 0.011 \text{ SEC.} \qquad \text{(EQ 12-1)}$$

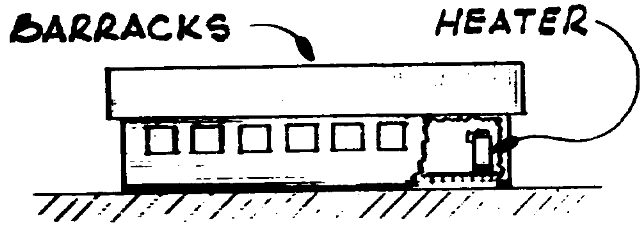
$T_a < 0.06$ SEC., THEREFORE SUPPORT IS RIGID (PARA. 12-3)

$$F_p = Z I_p C_p W_p = 0.30 \times 1.0 \times 0.75\, W_p = 0.225\, W_p$$
$$= 0.225 \times 350 = \underline{\underline{79 \text{ LBS.}}}$$

Figure E-4. Continued.

GIVEN: 1445 LB. WATER HEATER IN BARRACKS, SEISMIC ZONE 4.





REQUIRED: INVESTIGATE THE WATER HEATER FOR SEISMIC LOADS.

SOLUTION: WATER HEATER WILL BE CLASSIFIED AS BEING EQUIPMENT ON THE GROUND AND WILL BE CONSIDERED TO BE A RIGID BODY. SINCE FRICTION CANNOT BE USED TO RESIST LATERAL SEISMIC FORCES, THE WATER HEATER MUST BE RIGIDLY ATTACHED TO ITS FOUNDATION. BOLT WATER HEATER LEGS TO FLOOR.

$F_p = ZI\,(2/3\ C_p)\ W_p$

$Z = 0.4,\ I = 1.0,\ C_p = 0.75$ (SEAOC TABLE 1-H)

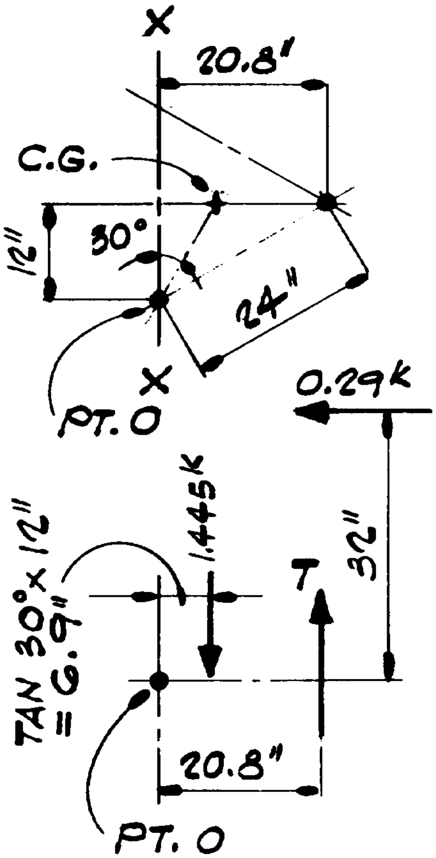
$F_p = 0.4 \times 1.0 \times 2/3 \times 0.75 = 0.20 W_p$

$F_p = 0.20\,W_p = 0.20 \times 1.445 = 0.29$ KIPS

$\underline{F_p = 0.29K}$ APPLIED AT C.G.

CHECK FOR OVERTURNING ABOUT POINT O.

$\Sigma M_{x-x} = 0$



$0.29^K \times 32'' < 1.445^K \times \text{TAN. } 30° \times 12''$

$9.28''^K < 10.0''^K$

OVERTURNING O.K.

CHECK FOR LOAD T IN LEG OF TRIPOD.

$\Sigma M_{x-x} = 0 = T \times 20.8 + 0.29 \times 32 - 1.445^K \times \text{TAN } 30° \times 12''$

$T = \dfrac{-9.28''^K + 10.0''^K}{20.8''} = 0.035$ KIPS COMPRESSION

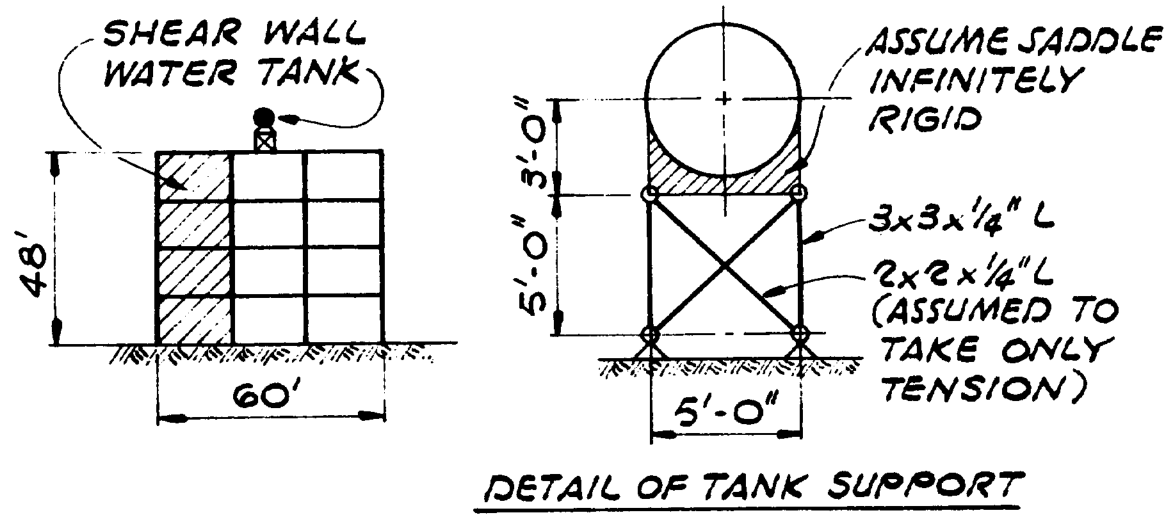
HENCE, USE NOMINAL ANCHOR BOLTS. USE 3-5/8"φ A.B.

ALLOW BASE SHEAR = $3(1.0^K) = 3K$

SHEAR O.K. 3.0K >> 0.29K

Note: SAME RESULTS IF CONSIDERED NON-BUILDING STRUCTURE V = 0.5 ZIW (SEAOC EQ 1-12)

Figure E-5. Continued.



GIVEN: WT. OF TANK + WATER = 10.0 K/ TRUSS

ZONE 2A SEISMIC AREA AND I = 1.0 OCCUPANCY
ASSUME ALL JOINTS ARE PIN CONNECTIONS.
ASSUME CROSS MEMBERS TAKE TENSION ONLY.
NEGLECT WT. OF SUPPORT MEMBERS.

REQUIRED: FIND THE DESIGN SEISMIC FORCE.

SOLUTION: HYDRO-DYNAMIC EFFECTS ARE NEGLECTED EVEN WHEN TANK IS PARTIALLY FULL. CALCULATION OF STIFFNESS OF TANK STRUCTURE: USE ENERGY METHOD TO FIND K.

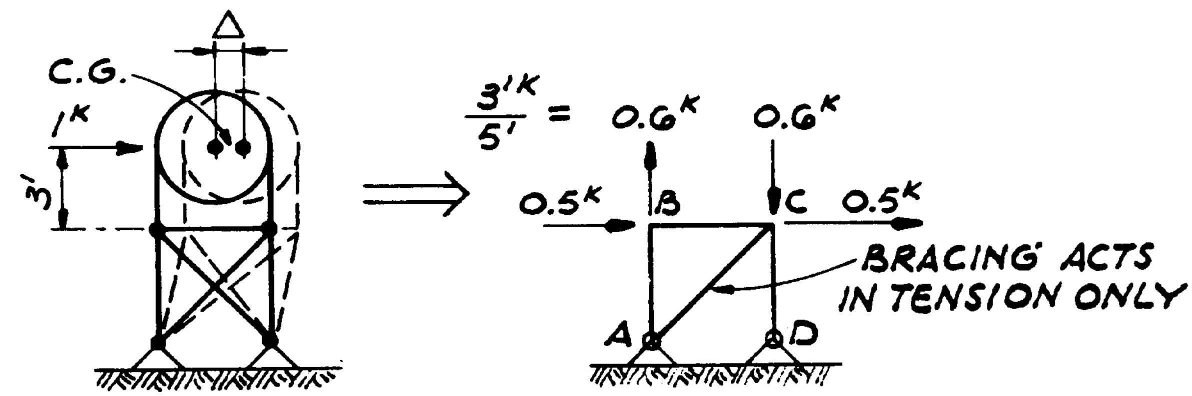


Figure E-6. Tank on a building.

COMPUTATION OF Δ : $1^K \cdot \frac{\Delta}{2} = \Sigma \frac{F^2 L}{2AE}$

MEMBER	LENGTH	AREA	F	F^2L/A
AB	5.00 FT.	1.44 IN.^{2}	+ .6 K	1.25
CD	5.00	1.44	− 1.6	8.89
CA	7.07	0.94	+ 1.414	15.03
				25.17

$$\therefore 1K \times \left(\frac{\Delta}{2}\right) = \frac{25.17 \frac{K^2-FT.}{IN^2} \times 12\ IN/FT}{2(30 \times 10^3\ K/IN^2)} = 0.5025 \times 10^{-2}\ IN.-K$$

$$\Delta = 1.005 \times 10^{-2}\ IN./K$$

$$K = \frac{1}{\Delta} = \frac{1}{1.005 \times 10^{-2}} = 99.5\ K/IN.$$

$$\therefore T_a = .32\sqrt{\frac{W}{K}} = .32\sqrt{\frac{10}{99.5}} = .102\ SEC.$$

(EQ 12-1)

T_a (EQUIPMENT PERIOD) = 0.102 > 0.06 SEC.
SUPPORT IS NOT RIGID (PARA. 12-3)
DESIGN AS FLEXIBLY MOUNTED (PARA. 12-4)

T (BLDG. PERIOD) IS CALCULATED TO BE 0.31 SEC.
REFER TO PARA. 12-4c (1)
T_a/T = 0.102/0.31 = 0.33 AND T < 0.5 SEC.
FIND A_p FROM FIGURE 12-3a

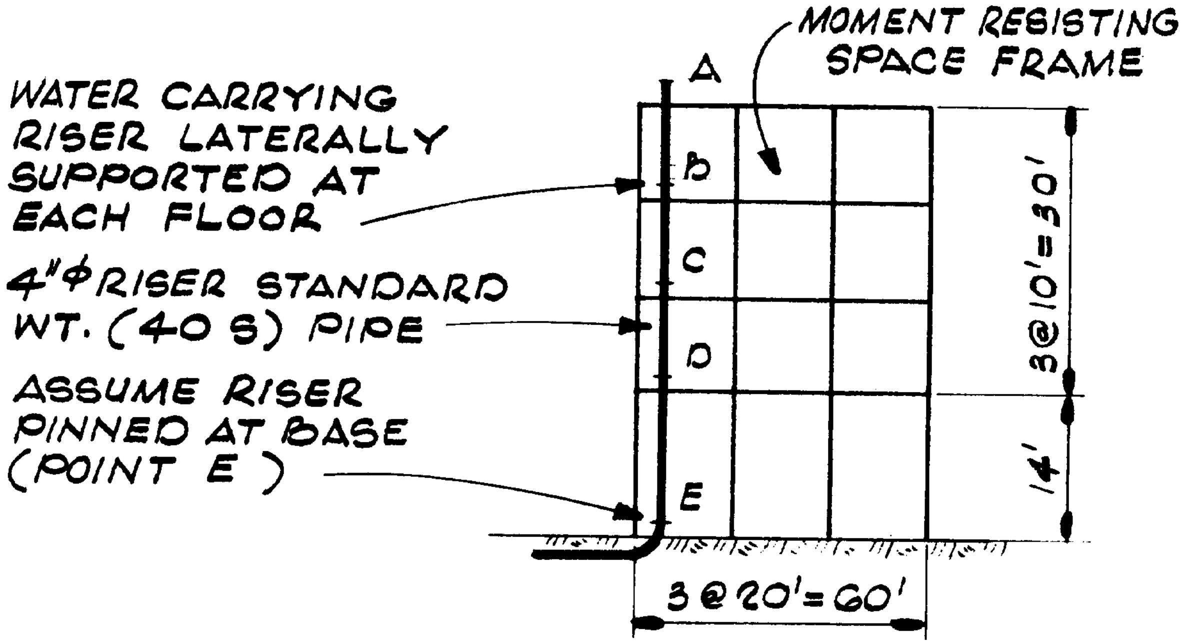
$$A_p = 1 + \left(\frac{0.33 - 0.10}{0.80 - 0.10}\right)(5.0 - 1.0) = 2.31$$

$F_p = ZIA_pC_pW_p$, (PARA. 12-4e, FORMULA 12-2)

WHERE $Z = 0.15$ (ZONE 2A)
$I = 1.0$
$C_p = 0.75$

$F_p = 0.15 \times 1.0 \times 2.31 \times 0.75\ W_p = 0.26\ W_p$
$F_p = 0.26 \times 10$ = 2.6 KIPS/TRUSS

Figure E-6. Continued.



GIVEN: RISER AS SHOWN IN MULTI-STORY BUILDING. SEISMIC ZONE 4
ESSENTIAL FACILITY BUT THE RISER IS NOT RELATED TO FIRE PROTECTION

REQUIRED: FIND SEISMIC FORCE AT EACH LATERAL RISER SUPPORT.

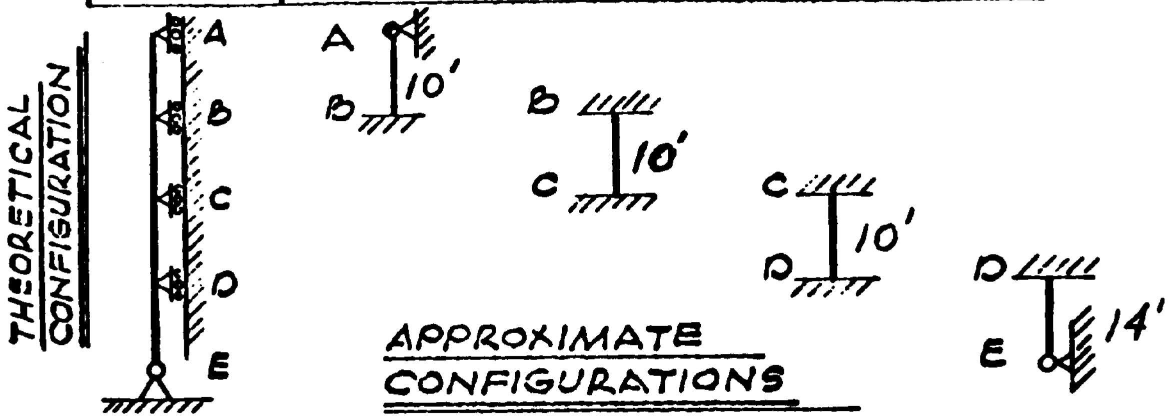
SOLUTION: AN APPROXIMATE SOLUTION WILL BE MADE.
FIRST INVESTIGATE THE ALLOWABLE SPAN FOR 4"φ (40 S) PIPE, THEN APPLY SEISMIC LOADING TO RISER.

1. IF PIPING SYSTEM IS RIGID
$F_p = ZI_pC_pW_p$ [PARA. 12-7d (2)]

2. IF PIPING SYSTEM IS NOT RIGID
$F_p = ZI_pA_pC_pW_p$ [PARA. 12-7d (3) & (4)]

Figure E-7. Water riser.

PIPE	APPROXIMATE END COND.	MAXIMUM RIGID SPANS (FIG. 12-4, 12-5 & 12-6)
A B	FIXED - PINNED	14'-6"
B C	FIXED - FIXED	17'-3"
C D	FIXED - FIXED	17'-8"
D E	FIXED - PINNED	14'-6'



PIPE SPANS ARE SHORTER THAN MAXIMUM RIGID SPAN LIMIT; ∴ $F_p = Z I C_p W_p$ APPLIES.

$Z = 0.4$ (ZONE 4) $I_p = I = 1.25$; $C_p = 0.75$

W_p = (WT. OF PIPE + CONTENTS) = (10.8 + 5.5) LB/FT × LENGTH

$F_p = 0.40 \times 1.25 \times 0.75 W_p = 0.38 W_p = 6.1$ LB/FT

POINT	APPROXIMATE TRIBUTARY LENGTH (FT.)	APPROXIMATE CONNECTION LOAD (LBS)
A	5.0	31
B	10.0	61
C	10.0	61
D	12.0	73
E	7.0	43

Figure E-7. Continued.